U.S. DEPARTMENT OF COMMERCE
National Technical Information Service

PB-260 316

REPORT TO THE OFFICE OF SALINE WATER. CHEMICAL AND BACTERIOLOGICAL TESTS ON INTAKE SEA WATER AND PRODUCT WATER. CARRIER CORPORATION FREEZING PROCESS PILOT PLANT, WRIGHTSVILLE BEACH, NORTH CAROLINA

ROBERT A. TAFT SANITARY ENGINEERING CENTER
CINCINNATI, OHIO

JULY 1[illegible] 2

254067

PB 260 316

REPORT TO THE OFFICE OF SALINE WATER

CHEMICAL AND BACTERIOLOGICAL TESTS

ON

INTAKE SEA WATER AND PRODUCT WATER

CARRIER CORPORATION
FREEZING PROCESS PILOT PLANT
WRIGHTSVILLE BEACH, NORTH CAROLINA

DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
PUBLIC HEALTH SERVICE
DIVISION OF WATER SUPPLY & POLLUTION CONTROL
ROBERT A. TAFT SANITARY ENGINEERING CENTER
CINCINNATI 26, OHIO

JULY 1962

BIBLIOGRAPHIC DATA SHEET	1. Report No.	2.	3. Recipient's Accession No. PB-260 316
4. Title and Subtitle Report to the Office of Saline Water. Chemical and Bacteriological Tests on Intake Sea Water and Product Water. Carrier Corporation Freezing Process Pilot Plant, Wrightsville Beach, N. C.			5. Report Date 6.
7. Author(s)			8. Performing Organization Rept. No.
9. Performing Organization Name and Address Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio. Div. of Water Supply and Pollution Control.			10. Project/Task/Work Unit No. 11. Contract/Grant No.
12. Sponsoring Organization Name and Address			13. Type of Report & Period Covered 14.

15. Supplementary Notes

16. Abstracts The chemical and bacteriological quality of water produced from sea water at Wrightsville Beach, North Carolina, by the Carrier Corporation freezing process is evaluated. Chemical, bacterial, and odor qualities of the product water were satisfactory.

17. Key Words and Document Analysis. 17a. Descriptors

17b. Identifiers/Open-Ended Terms

Wrightsville Beach(North Carolina)
*Water quality
Potable water
Chemical analysis
Bacteria
Sea water
Water reclamation
Federal agencies

17c. COSATI Field/Group 13B

18. Availability Statement	19. Security Class (This Report) UNCLASSIFIED	21. No. of Pages 23
	20. Security Class (This Page UNCLASSIFIED	22. Price

REPORT TO THE OFFICE OF SALINE WATER

Chemical and Bacteriological Tests

on

Intake Sea Water and Product Water

Carrier Corporation
Freezing Process Pilot Plant
Wrightsville Beach, North Carolina

Department of Health, Education, and Welfare
Public Health Service
Division of Water Supply & Pollution Control
Robert A. Taft Sanitary Engineering Center
Cincinnati 26, Ohio

July 1962

SUMMARY

The chemical and bacteriological quality of water produced from sea water at Wrightsville Beach, North Carolina by the Carrier Corporation freezing process was evaluated in June 1962 by the Public Health Service at the request of the Office of Saline Water. The results were:

Chemical Quality

The water produced met the Public Health Service Drinking Water Standards in all respects except iron content which was 0.4 ppm and 0.64 ppm (standard 0.3 ppm) on the composite samples tested.

Bacterial Quality

Tests over a four-day period (12 separate tests) on the product water using the Membrane Filter Technique showed total coliform organisms to be less than two per one hundred milliliters. The Public Health Service Standards for potable waters using this technique and sampling frequency states that coliforms should not exceed four per one hundred milliliters. The water thus meets potable Standards. The bacterial quality of the sea water being fed to the process at the time of these tests was good. Ability to meet the Standards with this feed water does not assure that Standards can be met when a more polluted feed water is used.

Odor Quality

The threshold odor of the product water was one and is considered satisfactory. The deaerated sea water also had relatively low odor (threshold four). Production of water of satisfactory quality from raw waters having high thresholds cannot be assured on the basis of these results.

Report on
Chemical and Bacteriological Tests
on
Intake Sea Water and Product Water
Freezing Process Pilot Plant, Wrightsville Beach, North Carolina

The Office of Saline Water requested the Public Health Service to evaluate the quality of the water from the sea water conversion freezing pilot plant being operated by the Carrier Corporation at Wrightsville Beach, North Carolina. It was the purpose of these tests to determine if the product water meets acceptable potable water Standards for chemicals and bacteria. Previous tests were made in April 1961 and reported in August 1961 to the Office of Saline Water. At the time of the 1961 tests, the plant was not operating in an efficient manner and product tests could not be fully interpreted.

THE PLANT

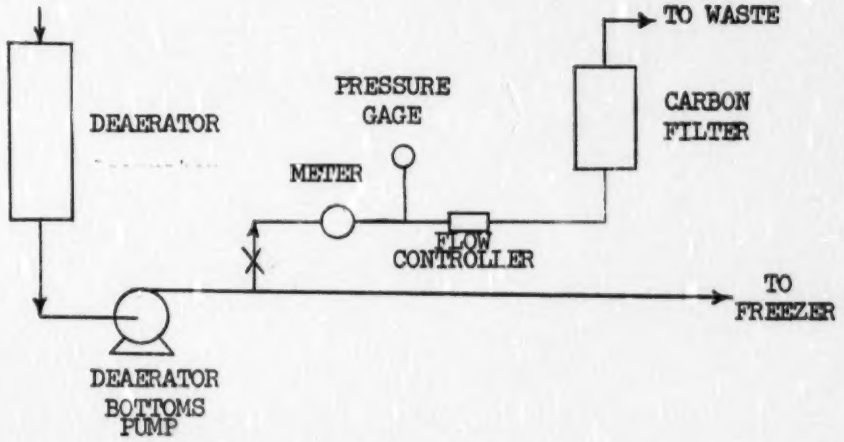
The 15,000-gallons-per-day plant at Wrightsville is designed to produce potable water from sea water through the direct freezing process in which the refrigeration effect is achieved through evaporation of sea water at approximately three millimeters of absolute pressure. The initial vacuum and the removal of noncondensible gases is achieved through the use of steam jet ejectors and a barometric leg condenser while the pumping of overhead water vapor is accomplished by absorption of the vapor into liquid lithium bromide. Approximately one-seventh of the product water is obtained by stripping the condensed overhead vapor from the lithium bromide solution, the reconcentrated LiBr then being cycled back to the absorber. Water is introduced through vertical pipes into the freezing chamber and about 50 percent is converted to fine ice crystals. The ice-brine slurry formed is

then pumped to the base of a wash column where the now solidified slush is pushed upward by hydraulic pressure. Clean wash water in the amount of 5 to 10 percent of production rate is sprayed on the top of the ice column, draining down through it by gravity. The washed ice crystals are then scraped from the top of this "icicle" column to a melt tank. This is the product.

CHEMICAL TESTING

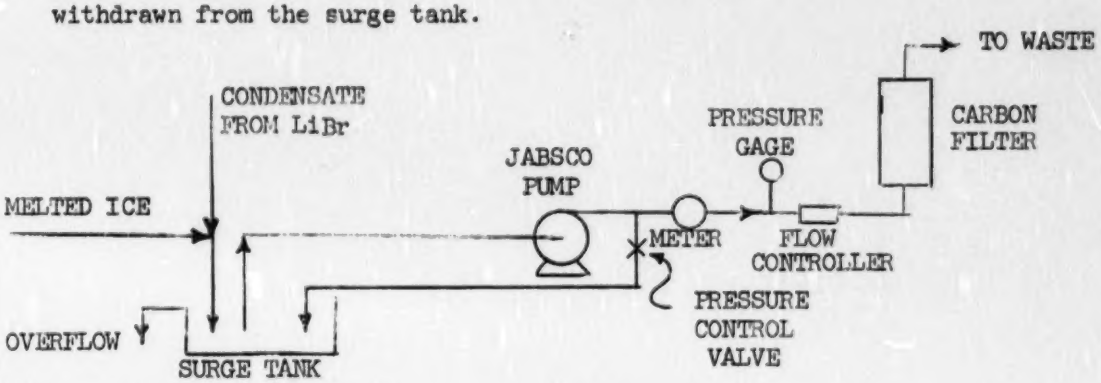
Sampling. The sea water feed to the freezing plant is taken from the Sound near the pilot plant, passes through a basket strainer (0.035-inch openings) and then into a packed deaerator where the oxygen and other non-condensibles are removed. The intake pipe is constructed of polyvinyl chloride. The deaerated water is pumped through precooling units and then into the freezer.

Feed water samples for chemical analyses were collected after the deaeration unit.



The carbon adsorption test unit was installed at this point.

The product water consists of the melted ice and the condensed vapors from the lithium bromide unit. Because the combined product flow rate was not steady, a polyvinyl chloride bucket was utilized as a surge tank. The product sample on which the chemical analyses were performed was the combined streams going into the surge tank. Feed to the carbon filter was withdrawn from the surge tank.



Two samples of feed water and two of the product water were collected as follows:

Feed 1 and Product 1:

Four hundred milliliters of each stream were added to a polyethylene bottle every six hours from 10:00 A.M., June 15 until 4:00 A.M., June 17 for chemical analyses. Grab samples for odor testing were collected as follows:

	Feed	Product
6/16	5:30 P.M.	5:00 P.M.
6/17	5:30 P.M.	5:00 P.M.
6/18	3:00 P.M.	2:00 P.M.

Feed 2 and Product 2:

Four hundred milliliters of each stream were added to a polyethylene bottle every six hours from 10:00 A.M., June 17 until 10:00 P.M., June 18.

The water vapor that is evaporated from the lithium bromide is condensed and stored in a surge tank from where it is returned to the system. One quart of this condensate was collected at the times listed below and composited:

6/17	6:00 P.M.
6/18	8:00 A.M.
6/18	4:00 P.M.
6/19	8:00 A.M.

Carbon Adsorption Units:

Feed Water: Start 6/12, 11:45 A.M.
End 6/18, 11:00 A.M.
Gallons Filtered, 3600

Product Water: Start 6/15, 3:00 P.M.
End 6/19, 4:00 A.M.
Gallons Filtered, 2010

Testing. The chemicals specified in the Public Health Service Drinking Water Standards (1961) were determined. These chemicals, the concentrations listed in the Standards, and the concentrations found in the samples are shown in Table 1. Not tested for were phenol, chromium, and cyanide. These materials would be unlikely to be in feed waters unless industrial pollution is present.

TABLE 1. TESTS FOR COMPLIANCE WITH PUBLIC HEALTH SERVICE DRINKING WATER STANDARDS

CARRIER FREEZING PROCESS, WRIGHTSVILLE BEACH, NORTH CAROLINA (JUNE 1962)

COMPONENT	PHS DRINKING WATER STANDARD (1961)		FEED WATER		PRODUCT WATER		LITHIUM BROMIDE CONDENSATE[A]
	RECOMMENDED MAXIMUM	GROUNDS FOR REJECTION	NO. 1	NO. 2	NO. 1	NO. 2	
	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
ALKYL BENZENE SULFONATE (DETERGENT)	0.5	--	--	--	<0.1	<0.1	0.00
ARSENIC	0.01	0.05	0.01	<0.01	<0.01	<0.01	<.01
BARIUM	--	1.0	1	1	0.005	0.005	N.D.
CADMIUM	--	0.01	N.D.	N.D.	N.D.	N.D.	N.D.
CARBON CHLOROFORM EXTRACT	0.2	--	.056	--	.074	--	--
CHLORIDE	250	--	18,425	19,112	173	127	--
CHROMIUM[B]	--	0.05	--	--	--	--	--
COPPER	1.0	--	0.09	0.07	0.1	0.9	--
CYANIDE[B]	0.01	0.2	--	--	--	--	--
FLOURIDE	1.7	2.2	1.9	2.1	0.08	0.08	.00
IRON	0.3	--	0.44	0.28	0.40	0.64	0.09
LEAD	--	0.05	N.D.	N.D.	N.D.	N.D.	N.D.
MANGANESE	0.05	--	N.D.	N.D.	N.D.	N.D.	0.0
NITRATE (NO_3)	45	--	N.D.	N.D.	N.D.	N.D.	--
PHENOLS[B]	.001	--	--	--	--	--	
SELENIUM	--	0.01	<0.01	<0.01	N.D.	N.D.	<0.01
SILVER	--	0.05	0.2	0.02	N.D.	N.D.	--
SULFATE	250	--	2,400	2,300	25	19	<1.0
TOTAL SOLIDS	500	--	35,560	36,230	346	245	--
ZINC	5		None	None	0.10	0.06	--

[A] THIS STREAM WAS SAMPLED TO DETERMINE CARRY-OVER

[B] NOT EXPECTED IN SAMPLES EXAMINED — NO ANALYSIS

N.D. NOT DETECTABLE

Several other chemical analyses were made as a matter of interest. The materials determined and the results are shown in Table 2.

The odor of the raw water and product water were tested.

Methods of Testing:

All tests were made in accordance with Standard Methods for the Examination of Water and Waste Water, 11 ed. American Public Health Association, New York 19, New York. Emission spectrographic methods were used to determine silver, barium, lead, lithium, and cadmium.

Results. The product water was well within the Standards except for iron which measured 0.4 and 0.64 ppm (Standard 0.3). Such a result would not be unexpected in a pilot plant operation where fresh metal surfaces are exposed to various forces. The two product samples varied in copper content by a substantial amount but were under the Standard. The chlorides and total solids were satisfactory.

The carbon chloroform extract (CCE) although within the Standard is of interest. More of this material was found in the product water than was found in the raw water. The extracts were oily and quite odorous. The exact chemical nature of this material has not been determined. It is possible that oily substances, paint solvent, or similar contaminants contributed to these samples. There is no body of knowledge at present on what materials in natural sea water are recoverable by this method.

The determinations in Table 2 are of additional interest in our evaluation of the chemical quality of the water. The alkalinity and hardness of the water are in a suitable range. A higher alkalinity would probably be desirable if the water were added directly to the water mains.

TABLE 2. CHEMICAL TESTS OTHER THAN THOSE CALLED FOR IN PHS STANDARDS

CARRIER FREEZING PROCESS, WRIGHTSVILLE BEACH, NORTH CAROLINA (JUNE 1962)

Component	Feed Water		Product Water		Lithium Bromide Condensate
	No. 1	No. 2	No. 1	No. 2	
	mg/l	mg/l	mg/l	mg/l	mg/l
Boron	1.9	1.6	0.05	0.02	0.00
Color	5	5	<5	<5	<5
Sodium	9,000	9,000	98	72	<1.0
Lithium	Trace	Trace	.03	.03	0.1
Potassium	360	360	4	3	<1.0
Total Phosphate (PO_4)	0.03	0.03	0.04	0.03	0.04
Total Alkalinity ($CaCO_3$)	102	108	5	4	4
Total Hardness ($CaCO_3$)	5,950	6,200	100	44	8
Dissolved Solids[a]	35,510	36,180	346	243	
Suspended Solids	46	50	0	3	
Volatile Solids	4,170	4,060	46	30	
Conductance ($Ohms^{-1}$)	4.5×10^{-2}	4.3×10^{-2}	6.1×10^{-4}	4.5×10^{-4}	
pH	7.9	7.8	6.6	6.4	
Chemical Oxygen Demand	--	--	N.D.	N.D.	
Odor	4[b]		1[b]		

[a] By Difference

[b] Threshold Odors

N.D. Not Detectable

The lithium bromide condensate water was examined for carry-over by determining lithium. A level of 0.1 ppm was found and .03 ppm was found in the product water. Other tests on the condensate indicate it to be of good quality. A small pickup of iron was noted.

Odor Quality. Threshold odor tests were run on the raw deaerated water and the product water on three days. The test is run by diluting the sample with odor-free water to the point where odor detection just occurs. Four or five people were used to judge each sample. The threshold number is the number of dilutions made to the point of detection. For example, a threshold of four means the original sample constitutes one-fourth of the diluted sample. The following results were obtained:

Threshold Number	Feed Water	Product Water
	Number of Times Observed	
1	-	7
2	2	3
4	5	3
8	5	-

Expressing the total panel results as the median, the raw water had a threshold of four, the product a threshold of one.

The odor quality is judged to be satisfactory. In practice, the consumers are the final judge of odor quality and while indications are that the odor is satisfactory, final judgment would await actual use of the water.

It should be pointed out that the deaeration step may reduce odor. The production of good quality water from the odor standpoint in these tests would not assure that good quality water could be produced from a highly odorous source.

Except for the slight excess of iron, the chemical quality of the product water was quite good. Considering the chemicals in the feed water, the freezing process has done a good job of producing potable water from the chemical standpoint.

BACTERIOLOGICAL TESTING

Sampling. Beginning on June 15, 1962 and continuing for four consecutive days, samples were collected at 4:00 A.M., 10:00 A.M., and 4:00 P.M. from:

1. The raw sea water intake after passing a rough screen and following deaeration.
2. The finished ice product prior to melting and mixing with the condensate return from the lithium bromide unit.
3. The brine waste.

On the second day of operation, ice production was interrupted for five hours due to a breakdown.

Tests Performed. Each sample was tested for:

1. Total coliform enumeration by membrane filter.(1)
2. Fecal coliform enumeration by membrane filter method using MacConkey's Modified Medium, incubation 18-20 hours at 45°C. (nonstandard).(2-8)
3. Fecal streptococcus enumeration by membrane filter method using KF agar medium, incubation 48 hours at 35° (nonstandard).(2-8)
4. Tests on one sample from each of the three sources once a day for total bacterial enumeration by membrane filter method using M-Enrichment broth, incubation 18-20 hours at 35°C. (nonstandard).

5. Tests to confirm fecal coliform colonies from one saline intake sample; picked from membrane filter, planted in EC medium, incubation 18-20 hours at 45°C.

Results. Bacterial densities were determined as count per one hundred milliliters of sample. These results are shown in Tables 3, 4, and 5. Table 6 summarizes these results. Confirmation of fecal coliforms planted in EC medium was one hundred percent for 10 colonies picked.

Discussion. The coliform group has been the classical measure of the sanitary quality of water. The coliform group density in the raw sea water at the Wrightsville intake averaged 30/100 milliliters representing a relatively good quality sea water; however, sea water in the open ocean would probably be free from the coliform group. There are no bacterial standards for sea water to be used for processing to a potable fresh water. Bathing beach standards vary from state to state but may serve as a guide. The maximum coliform density for overlying waters for approved shellfish beds is 70/100 milliliters. Eventually, bacterial standards for sea water may be developed when sufficient data on the bacterial quality of the finished water produced from sea waters of various levels of pollution are available for study.

Recent research has developed refinements in the tests for indicators of pollution. The coliform group may be divided in those organisms (fecal coliforms) derived from feces of warm-blooded animals and a group (non-fecal) from unknown sources. Likewise, the addition of this fecal streptococcal test is another index of microorganisms derived chiefly from fecal (warm-blooded) pollution. Both the fecal coliforms and the streptococci are a measure of fecal pollution in a stream, sea water, or wherever they may be

TABLE 3. CARRIER FREEZING PROCESS, WRIGHTSVILLE BEACH, NORTH CAROLINA (JUNE 1962)

Sample: Saline Intake

Time Collected	Total Coliform Count/100 ml.	Fecal Coliform Count/100 ml.	Strep. (Fecal) Count/100 ml.
Fri., June 15, 4 A.M.	40	8	21
10 A.M.	26	16	7
4 P.M.	80	72	270
Sat., June 16, 4 A.M.	80	42	180
10 A.M.	8	5	13
4 P.M.	36	12	30
Sun., June 17, 4 A.M.	90	33	38
10 A.M.	4	4	16
4 P.M.	32	16	14
Mon., June 18, 4 A.M.	36	35	16
10 A.M.	16	10	6
4 P.M.	36	19	2

Total Count/100 ml.	
June 15, 4 A.M.	8200
June 16, 4 A.M.	12000
June 17, 4 P.M.	9900
June 18, 4 P.M.	44000

TABLE 4. CARRIER FREEZING PROCESS, WRIGHTSVILLE BEACH, NORTH CAROLINA (JUNE 1962)

Sample: Finished Product (Ice)

Time Collected	Total Coliform 100 ml.	Fecal Coliform 100 ml.	Fecal Strep. 100 ml.
Fri., June 15, 4 A.M.	2	<2	<1
10 A.M.	<3	<2	1
4 P.M.	<2	<2	1
Sat., June 16, 4 A.M.	6	5	4
10 A.M.	No Sample	--	--
4 P.M.	<1	<1	4
Sun., June 17, 4 A.M.	2	<1	<1
10 A.M.	<1	<1	<1
4 P.M.	1	1	1
Mon., June 18, 4 A.M.	1	<1	2
10 A.M.	<1	2	<1
4 P.M.	1	<1	<1

	Total Count/100 ml.
June 15, 4 A.M.	1500
June 16, 4 A.M.	1800
June 17, 4 P.M.	1000
June 18, 4 P.M.	850

TABLE 5. CARRIER FREEZING PROCESS, WRIGHTSVILLE BEACH, NORTH CAROLINA (JUNE 1962)

Sample: Brine Waste

Time Collected	Total Coliform 100 ml.	Fecal Coliform 100 ml.	Fecal Strep. 100 ml.
Fri., June 15, 4 A.M.	12	2	12
10 A.M.	5	4	6
4 P.M.	160	58	81
Sat., June 16, 4 A.M.	110	37	124
10 A.M.	10	6	11
4 P.M.	4	4	4
Sun., June 17, 4 A.M.	124	90	72
10 A.M.	20	26	34
4 P.M.	16	11	6
Mon., June 18, 4 A.M.	28	30	28
10 A.M.	8	8	10
4 P.M.	34	11	4

	Total Count/100 ml.
June 15, 4 A.M.	5900
June 16, 4 A.M.	3700
June 17, 4 P.M.	2700
June 18, 4 P.M.	34000

TABLE 6. GEOMETRIC MEANS OF BACTERIAL COUNTS

	Sea Water (Raw)	Finished Water (Ice)	Brine Waste
Total Coliforms	30/100 ml.	<2/100 ml.	22/100 ml.
Fecal Coliforms	16/100 ml.	<2/100 ml.	13/100 ml.
Non-fecal Coliforms	14/100 ml.	<2/100 ml.	9/100 ml.
Streptococci	20/100 ml.	1/100 ml.	17/100 ml.
Colony Count (MF)	14,000/100 ml.	1200/100 ml.	6700/100 ml.

found. Currently, these are nonofficial procedures in the evaluation of potable waters but serve a very useful purpose in pollution studies. The fecal coliform density in the untreated sea water averaged 16/100 milliliters and the fecal streptococcal density was 20/100 milliliters. These numbers represent the actual organisms present as fecal pollution and their essential removal, plus the elimination of the non-fecal coliform group, represents a good product from the bacteriological quality viewpoint.

The bacterial colony count represents all the individual bacteria able to grow on a nonselective nutrient medium by these specific test procedures. This count would include the coliform group (negligible value compared to total) but does not include the streptococcal group. Such a colony count has no sanitary significance in the evaluation of a potable water. This data was included to give an estimate of the possible bacterial population which could survive the freezing process and appear in the finished product. Reference to Table 6 gives an average colony count of 14,000/100 milliliters in the sea water with approximately 8.6 percent surviving in the finished water, 47.9 percent discarded in the brine waste, and 43.5 percent unaccountable which may be presumed to be the die-off during processing. It is not known whether these bacteria resulting in the colony count react in the same way to the freezing process as the coliform group and the streptococcal group. However, the possibility must be considered that the pollution microorganisms do behave in the same way until definite proof to the contrary is available. Based on this assumption, a water containing 14,000 coliforms per one hundred milliliters would result in a considerable number of coliforms in the finished water. Further experimental work on this point is recommended.

The finished water on an average (Table 6) had no coliforms (less than 2/100) and one streptococcus per one hundred in the samples examined. It can be concluded that the finished water produced from this sea water is of satisfactory bacterial quality for a potable water. It would be essential, of course, to chlorinate the finished water if used as a drinking water supply, which is in accordance with good public health practice for water supplies.

REFERENCES

1. Standard Methods for the Examination of Water and Wastewater, 11th ed. p. 477-513, (1960). Am. Pub. Health Assoc., New York 19, New York.

2. Kabler, P. W. and Clark, H. F. Coliform Group and Fecal Coliform Organisms as Indicators of Pollution in Drinking Water. J.A.W.W.A., vol. 52, p. 1577-1579 (1960).

3. Geldreich, E. E. et al. The Coliform Group. II. Reactions in EC Medium at 45°C. Appl. Microbiol., vol. 6, p. 347-348 (1958).

4. Geldreich, E. E. et al. Type Distribution of Coliform Bacteria in the Feces of Warm-Blooded Animals. J.W.P.C.F., vol. 34, (1962). In press.

5. Geldreich, E. E. et al. Fecal Coliform Flora of Soils from Various Geographical Areas. J. Appl. Bact. (Brit.) vol. 25, (1962). In press.

6. Kenner, B. A., Clark, H. F. and Kabler, P. W. Fecal Streptococci. I. Cultivation and Enumeration of Streptococci in Surface Waters. Appl. Microbiol., vol. 9, p. 15-20 (1961).

7. Kenner, B. A., Clark, H. F. and Kabler, P. W. Fecal Streptococci. II. Quantification of Streptococci in Feces. Am. J. Pub. Health, vol. 50, p. 1553-1559 (1960).

8. Bartley, C. H. and Slanetz, L. W. Types and Sanitary Significance of Fecal Streptococci Isolated from Feces, Sewage and Water. Am. J. Pub. Health, vol. 50, p. 1545-1552 (1960).

ACKNOWLEDGMENTS

Over-all planning and coordination of the study:

Walter Rinne	Office of Saline Water
F. M. Middleton	Public Health Service, Robert A. Taft Sanitary Engineering Center

Participating in the study were the following members of the Public Health Service, Division of Water Supply & Pollution Control:

Arthur N. Masse	Field Engineer
Clifton B. Huff	Field Bacteriologist
Harold F. Clark	Bacteriological Planning & Coordination
Robert Kroner and Staff	Chemical Testing
Robert T. Williams	Chemical Testing
Richard A. Dobbs	Chemical Testing
Edwin F. Barth	Chemical Testing

Assistance was generously given by the following Carrier Corporation personnel, Wrightsville Beach, North Carolina:

Robert Fullerton

Sam Moore

Will Hahn

Bill Bingham

Final Report: F. M. Middleton

H. F. Clark